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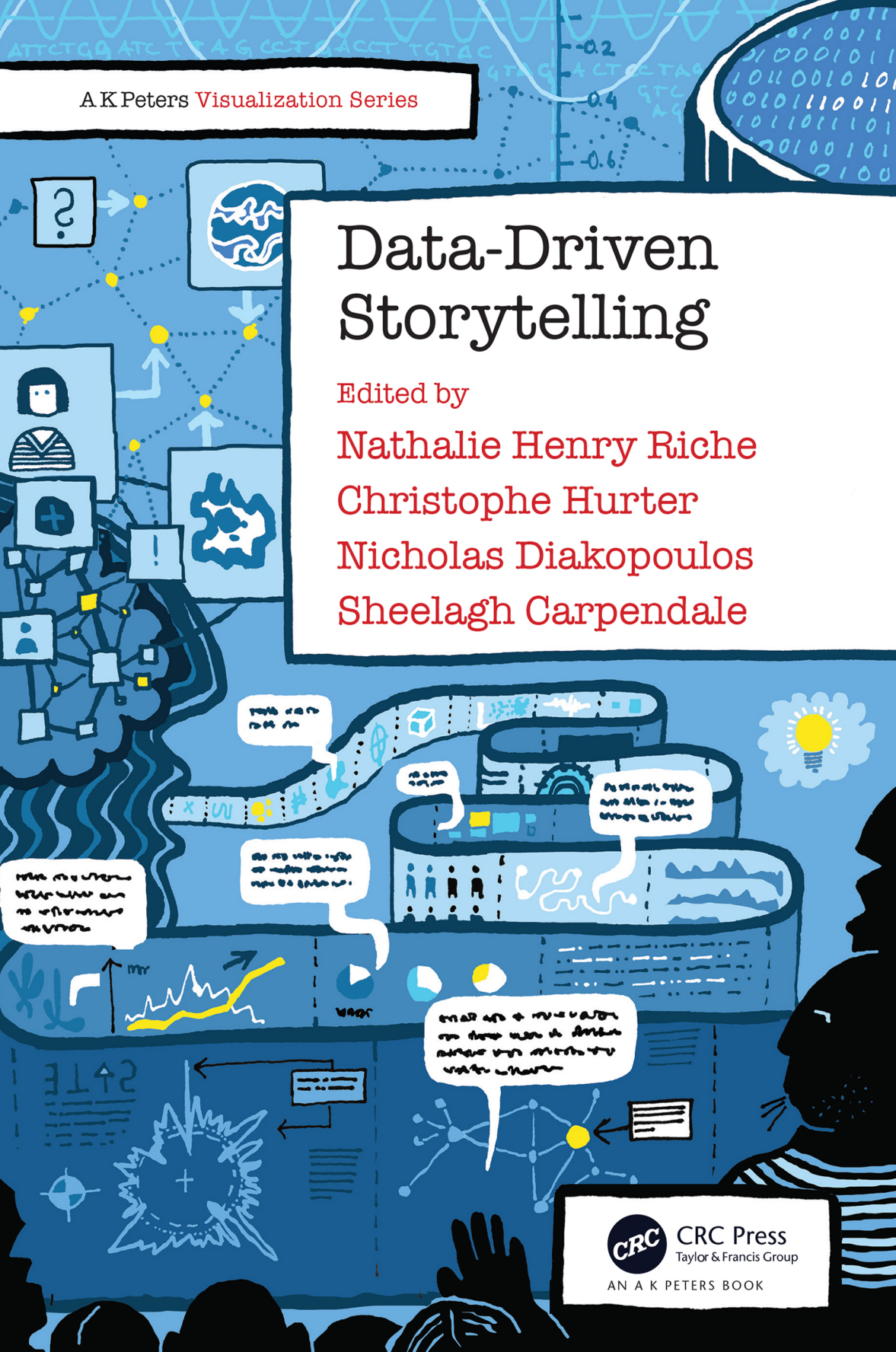
Data-Driven Storytelling

Edited by
Nathalie Henry Riche
Christophe Hurter
Nicholas Diakopoulos
Sheelagh Carpendale



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Data-Driven Storytelling

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Nathalie Henry Riche, Christophe Hurter, Nicholas Diakopoulos, and Sheelagh Carpendale
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Kennedy and Stefan both contributed to discussions at the seminar which informed several of the chapters.

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Nathalie would like to thank Microsoft Research for supporting this effort and the seminar leading to this book.

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Christophe would like to thank the French National Agency for Research (Agence Nationale de la Recherche—ANR) under grant ANR-14-CE24-0006-01 project "TERANOVA".

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Sheelagh would like to thank her research support from National Science and Engineering Research Council (NSERC), Alberta Innovates Technology Futures (AITF), and SMART Technologies. She would also like to thank her collaborators and students for on-going stimulating intellectual discussions.

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Many of the ideas and perspectives that informed Jason's contributions to the Dagstuhl seminar and subsequent chapter were informed by discussions over the years with giCentre colleagues.

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Xaquín thanks Microsoft for allowing him to meet the most inspiring collection of talent in this seminar, his dad Xoán G. (his first dataviz mentor), Cris and Roi for "forcing" him to come to Dagstuhl.

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CHAPTER 1

Introduction

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Today, data visualizations are everywhere. They form a significant and often integral part of contemporary media. Stories supported by facts extracted from data analysis proliferate in many different ways in our analog and digital environments including printed infographics in magazines, animated images shared on social media, and interactive online visualizations tightly integrated with news stories on leading media outlets. However, while data visualization may be at the heart of data-driven stories, the concepts are not synonymous. We explore these distinctions in this book.

The appearance of several landmark books such as Bertin's *Semiology of Graphics: Diagrams, Networks, Maps* (original French 1967, English translation 1983), Tukey's *Exploratory Data Analysis* (1977), Tufte's *The Visual Display of Quantitative Information* (1984), and Cleveland and McGill's *Dynamic Graphics for Statistics* (1988) set the stage for the emergence of a recognized area of research in visualization by the late 1980s. This emergence was fueled by the increasingly prevalent possibility of using computers to make data visual and interactive and was inspired by the popular idiom that "a picture is worth a thousand words." While the research community has favored phrases such as "scientific visualization," "knowledge visualization," and "information visualization," in general, media tends to use the more encompassing phrase "data visualization." Due to the importance of visualization to data-driven stories in journalism, we also use the phrase "data visualization."

Data has been represented visually from the early history of humans. Perhaps the oldest examples are those documented by Marshack, where he shows examples of keeping records through scratches on surfaces such

as Ishango bones (18,000–20,000 BC) and Lebombo bones (35,000 BC) (Marshack 1991). While these considerably predate written language, humans were clearly using visual representations to help themselves understand their world. If the ability to make scratches on bones is considered the first technology boon to data visualization, large advances in what is possible to achieve with data visualization can be associated with the availability of developing technologies. In broad steps, this includes the use of clay tablets in Mesopotamia, the development of paper in Egypt, Johannes Gutenberg's printing press in 1440, Konrad Zuse's computer in 1940, and most recently in the late 1980s when Tim Berners-Lee made the Internet widely accessible via the World Wide Web. In terms of our focus on data-driven stories, this last factor of making computational power and prowess widespread has been crucial. It is this factor that has made it possible for all types of media to consider incorporating evidence, portrayed by the visualization of the data that supports a given story, directly into the presentation of that story.

We think this movement towards data-driven stories, which is apparent in both the data visualization research community and the professional journalism community, has the potential to form a crucial part of keeping the public informed, a movement sometimes referred to as the democratization of data – the making of data understandable to the general public. This exciting new development in the use of data visualization in media has revealed an emerging professional community in the already complex group of disciplines involved in data visualization. Data visualization has roots in many research fields including perception, computer graphics, design, and human-computer interaction, though only recently has this expanded to include journalism.

RESEARCH IN DATA VISUALIZATION: FROM UNDERSTANDING TO EXPLORATION TO DATA STORYTELLING

Early research in data visualization focused on producing static images and quantifying the perception of different visual encodings to understand data visually (Card, Mackinlay, and Shneiderman 1999). The vast majority of research since then has focused on designing and implementing novel interfaces and interactive techniques to enable data exploration. Major advances in visual analytics and big-data initiatives have concentrated on integrating machine learning and analysis methods with visual representations to enable powerful exploratory analysis and data mining (Thomas and Cook 2005). As interactive visualizations

play an increasing role in data analysis scenarios, they also started to appear as a powerful vector for communicating information. The popularity of JavaScript Web technology and the availability of the D3 toolkit (Bostock, Ogievetsky, and Heer 2011) also made it possible for a wider range of people to create data visualizations. Being able to easily share interactive data visualizations on the Web also increased the democratization of interactive visualizations. Since the field is mature enough, it is now time to understand how these powerful interactive and dynamic data visualizations can play a role in communicating information in novel ways.

PRACTICE IN DATA JOURNALISM: FROM COMMUNICATION TO DATA EVIDENCE TO DATA STORYTELLING

Journalism has always been about communication, finding relevant stories and disseminating them publically, observing events, gathering information, and telling this information to the general public in a manner that can be understood and is both interesting and relevant (Kovach and Rosenstiel 2007). There has been an increasing onus on the quality of this information, from the right to protect an information source, to increasing interest in documented evidence, as in photographs, audio recordings, and video recordings, all of which can be thought of as types of data. There has also been a growing consciousness that some of today's most relevant stories are buried in data. This data can be quite hard to understand in its raw formats but can become much more generally accessible when visualized. Journalists have not only begun to use standard data visualizations such as charts and maps in their stories, but are also creating new ones that are tailored to the particular data type and to the message of the story they are writing. Since journalists are now able to easily share interactive data visualizations on the Web, the democratization of data visualization is accelerating with new compelling data visualizations emerging in the media daily. This has led to extensive and practical progress on the challenges of data-driven storytelling. News sites like *The New York Times*,[*] *FiveThirtyEight*,[†] *Bloomberg*,[‡] and *The Washington Post*[§] were early movers in capturing the surge of attention and interest in consuming data-driven news by the public. By carefully

[*] http://www.nytimes.com/.
[†] http://fivethirtyeight.com/.
[‡] http://www.bloomberg.com/.
[§] http://www.washingtonpost.com/.

structuring the information and integrating explanation to guide the consumer, journalists help lead readers towards a valid interpretation of the underlying data. In parallel to the last section on the visualization researcher perspective, we can also say that it is now time to learn how these powerful interactive and dynamic data visualizations play a role in communicating information in novel ways.

FORGING NEW INTERDISCIPLINARY PERSPECTIVES

At the time of formulating the possibility of this book, there was little overlap and collaboration between the two major communities involved: professional journalists who are at the forefront of making data-driven stories and academic researchers who are exploring research questions in regard to the role visualization can play in storytelling with data. This gap between research and practice has been widening as novel and innovative examples and genres of storytelling with data flourish in the media quite separately from the knowledge being built by the research community. The goal of this book is to try to close this gap by bringing together the voices of leading researchers and practitioners on data-driven storytelling. The chapter topics and their content were defined by authors with representation and participation from both communities.

Because of the rapid and practical advances in data-driven storytelling and its increasingly widespread use, we gathered several of the top practitioners from journalism and design together with visualization researchers to discuss the challenges and opportunities of data-driven communication during a Dagstuhl Seminar. Schloss Dagstuhl,[*] a unique venue sponsored by the German government, is a place where computer science researchers can meet to discuss currently important research questions. Dagstuhl encourages interdisciplinary discussion that includes leading thinkers from academia and industry. Founded in 1990, it has earned an international reputation as an incubator for new ideas. The four editors of this book organized the 16061 seminar[†] February 7th–12th, 2016. During these 5 days, a carefully selected group of 42 thinkers with diverse backgrounds: journalists, designers, perception, human-computer interaction, and visualization researchers, reflected, exchanged, and synthesized knowledge on data-driven storytelling, which led to this book.

[*] http://www.dagstuhl.de/en/.

[†] http://www.dagstuhl.de/en/program/calendar/semhp/?semnr=16061.

In brief, the aims of the seminar were as follows:

1. To bring together academic and industrial researchers from the human-computer interaction, cognitive psychology, information visualization, and visual analytics research communities, as well as storytelling experts from data journalism, design, art, and education.
2. To prepare a data-driven storytelling research agenda that includes a definition of data-driven storytelling, to compile examples, and to provide a detailed description of research directions in this space, and to offer a motivating list of research opportunities and challenges.
3. To investigate how the evaluation of data-driven stories can be done, including via expert critique, as well as through studies of audience comprehension, engagement, biases, and visualization literacy.
4. To discuss the ethics of data-driven storytelling authoring, identifying possible sources of bias and investigating how the lie factor of static visualizations applies to different media.
5. To compile examples of good and bad practices in application domains (data journalism, design, art, and education) and report on current processes and practices to create data-driven stories.
6. To formalize and explore the design space for novel consumption experiences in each domain. In particular, to reflect on the various advantages of different devices and input technologies (e.g., mobile phones, touch, or pen-enabled interfaces).
7. To formalize and explore the design space for novel authoring interfaces to democratize data-driven storytelling, focusing on audiences that are not able to program their own custom experiences.
8. To build individual collaborations between the seminar attendees and hence, build the community around data-driven storytelling research.

The chapter topics in this book were chosen through full group discussions. Once the topics were selected, smaller subgroups with particular interest and expertise in a given topic discussed the topic in depth. Thoughts presented in this book are the results of these conversations that

were initiated at the seminar and were pursued over a year and finalized as chapters in this book.

NOTES ON TERMINOLOGY

Since this book has emerged from cross-discipline discussions, it seems appropriate to define, for use in this book, common terms in use in all communities with often slightly variant definitions. We include the definitions of key concepts for data-driven stories below.

InfoVis: the definition from Card, Mackinlay, and Shneiderman (1998) as "the use of computer-supported interactive visual representations of abstract data to amplify cognition" still serves well and provides us with our working definition of data visualization. In other words, we see data visualization as a more inclusive term in that the term "data" covers all visualization variations (scientific vis, knowledge vis, information vis), which is important because data-driven stories do not limit themselves to any particular type of data. Thus for this book, we define the following terms:

Data visualization: "The use of interactive, dynamic, and responsive visual representations of data to amplify cognition." However, this definition requires some unpacking.

Interactive: "Mutually or reciprocally active." For example, interactive play between children is when two or more children are acting and responding to each other's acts. Interactive computer systems then are those where a person acts and the computer system responds to his and her actions and vice versa.

Dynamic: "Often continuous actions or changes." On a computer, many sorts of dynamics are possible such as animations, replays, stop motion, etc., that while possibly being very useful in telling a story, may not be actually interactive.

Responsive: "An action that is triggered by a previous act." The previous act could be an action in the narrative or an action taken by a person.

Data: "Gathered, collected, modeled and produced details, calculations, and measurements, often assumed as facts, and forming the basis of reasoning, analysis, and understanding."

Abstract data: We unpack this term from Card et al.'s definition as explaining why we omit it in our definition of "data visualization." Some data is concrete as in coordinates like latitude and longitude, which indicate a definitive place. Other data is less concrete in that it is derived from concrete data, for example, speed is derived from time and distance. On a continuum, data can become less and less concrete as it incorporates ideas such as love and hate and expressions of these ideas, such as poetry. While InfoVis is a research discipline that focuses on the challenges of visualizing abstract data, in terms of data-driven stories, we need no such distinction. A data-driven story can be based on any type of data that has emerged from any place on the data continuum from concrete to abstract.

Amplify cognition: To amplify cognition we must in some manner enhance the process of cognition, which is defined as "the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses." Visualizations can enhance this by assisting memory (providing externalization of complex factors) and by easing comprehension (e.g., by creating representations that appropriately leverage perception).

Narrative: The definition according to the *Oxford English Dictionary* is "an account of a series of events, facts, etc., given in order and with the establishing of connections between them." Narratives are a sequence of events in a set order.

Stories: Stories are based on a set of events from a narrative, but they may adjust the presentation by changing the order, shortening the length, adding extra context, etc. While a story is based on a narrative, it is an expression of the creative prerogative to provide interest, emphasis, etc. Stories have been used since ancient times to transfer knowledge and information over time, e.g., Homer, religious parables, and folktales. Stories package information to aid memory and recall by embedding information into characters, settings, relationships, and events.

Data-driven stories (DDSs): These are stories that are data-driven in that they start from a narrative that either is based on or contains data and incorporates this data evidence, often portrayed by data graphics, data visualizations, or data dynamics, to confirm or augment a given story. A DDS often incorporates the visual data

representations directly into the presentation of the story. A DDS can enhance a narrative with capabilities to walk through visual insights, to clarify and inform, and to provide context to visually salient differences.

AUDIENCE OF THIS BOOK

This book introduces key concepts on data-driven storytelling bridging several domains and pointing to seminal research and exemplary stories from practitioners. Every chapter provides a wealth of examples of DDSs along with different analyses that are discussed from different perspectives. This discourse can serve as an initial corpus for the rapidly expanding practice around DDSs. Thus, it offers an important resource for students at all levels but particularly for advanced undergraduate and graduate students in computer science, design, journalism, and communication.

Each chapter highlights challenges and research opportunities for data-driven storytelling, synthesizing knowledge from practitioners and leading researchers in the field. We envision that it can become a seminal book for academic and industrial researchers who aim to push the state of the art in data visualization.

As data-driven storytelling is compelling in a wide range of scenarios, we envision that practitioners and data enthusiasts from many domains will find inspiration, knowledge, and practical pointers for data-driven storytelling. For example, DDSs are compelling in enterprise scenarios where the output of data analysis (often reports and slide-based presentations) and business intelligence has to be conveyed to decision makers. In education scenarios, DDSs can be an effective medium to explain complex concepts or to illustrate biological or physical mechanisms. Finally, in many other scenarios, from journalism to art and entertainment, DDSs can help communicate complex findings to a broad audience in an engaging manner.

Data-story creators may use this book as a handbook to guide the design and evaluation of the DDSs that they create. Discussions in the chapters are grounded in real-world examples from leading news media outlets and companies, and incorporate discussions from the authors of these pieces on the design process and experience, providing valuable knowledge for the practice of crafting DDSs. The chapters also point to many fundamental research findings and open new research questions that can serve to inform future DDS research including such factors as leveraging design and discovering appropriate strategies for evaluation.

BOOK STRUCTURE

The authors in this book have a wide range of backgrounds as researchers and professionals in the fields of data visualization, design, perception and human-computer interaction, and data journalism. This diversity offers different and rich perspectives on the topic, and is revealed via the multiple facets written in each chapter. This book covers topics on perceptual and cognitive foundations of data-driven storytelling (see Chapter 2), the content and structure of DDSs (see Chapters 3–6), various data-driven storytelling processes (see Chapters 7–10), and the evaluation of DDSs (see Chapter 11).

Chapter 2: Storytelling in the Wild: Implications for Data Storytelling

This chapter lays out the perceptual and cognitive foundation of how humans understand and perceive events, stories, data graphics, and ultimately visual storytelling. Creating meaningful and memorable stories based on data is challenging, a craft that brings together disparate strands of inquiry. There is the structure and understanding of events from which stories are crafted. There is the structure of stories and related kinds of discourse, descriptions, explanations, and conversations. There is visual storytelling, ancient and modern. There is the understanding of memory for and uses of graphic displays. Then there are the constraints of the media, print and digital, static and interactive, and the newsworthiness of the stories. This chapter points to a substantial corpus of existing research and highlights open questions and challenges for designing effective DDSs.

Chapter 3: Exploration and Explanation in Data-Driven Storytelling

This chapter reflects on exploratory and explanatory aspects of DDSs. Exploratory aspects give readers freedom and control over how they experience the story, while explanatory aspects provide context and interpretation for the reader and allow the authors to communicate a particular narrative. The authors argue that DDSs can have high amounts of both explanation and exploration. To this end, the authors view data stories through multiple dimensions. They examine the flexibility and interpretation provided in the data stories' view, the data they focus on, and the sequences in which the data can be viewed. Examples from DDSs are used to illustrate how differing amounts of exploration and explanation can be provided in practice. Viewing these as complementary aspects could lead to new ways of integrating exploration and explanation in DDSs.

Chapter 4: Data-Driven Storytelling Techniques: Analysis of a Curated Collection of Visual Stories

Integrating data visualization into narrative stories has now become commonplace. Authors are enabling new reader experiences, such as linking textual narrative and data visualizations through dynamic queries embedded in the text. Novel means of communicating position and navigating within the narrative also have emerged, such as utilizing scrolling to advance narration and initiate animations. This chapter advances the study of narrative visualization through an analysis of a curated collection of DDSs shared on the Web. Drawing from the results of this analysis, it presents a set of techniques being employed in these examples, organized under four high-level categories that help authors tell stories in creative ways: communicating narrative and explaining data, linking separated story elements, enhancing structure and navigation, and providing controlled exploration. The benefits of each storytelling technique along with a number of example applications of the ideas in DDSs are discussed. Furthermore, the evolution of the field and areas for future research are outlined.

Chapter 5: Narrative Design Patterns for Data-Driven Storytelling

This chapter introduces the concept of narrative design patterns that aim to facilitate the shaping of compelling DDSs. There are many different ways storytellers can narrate the same story, depending on their intentions and their audience. Here, the authors define and describe a set of these narrative design patterns that can be used on their own or in combination to tell data stories in a myriad of ways. The authors then analyze 18 of them, and illustrate how these patterns can help storytellers think about the stories they want to tell and the best ways to narrate them. Each pattern has a specific purpose, for example, engaging the audience, evoking empathy, or creating flow and rhythm in the story. The authors assume storytellers already know what story they want to tell, why they want to tell it, and who they want to tell it to. These patterns may not only facilitate the process of creating compelling narratives, but stimulate a wider discussion on techniques and practices for data-driven storytelling.

Chapter 6: Watches to Augmented Reality: Devices and Gadgets for Data-Driven Storytelling

This chapter discusses different device form factors and their affordances and characteristics for different storytelling settings. A wide range of form

factors for data-driven storytelling, including not only the obvious electronic "devices," but also more diverse media such as tangible props (i.e., things that people can pick up and hold, gesticulate with, and so on) are considered. The latter are worth considering because they can give insights into how data storytelling might occur in futuristic mixed-reality digital environments that may be enabled by the current rapid progress in virtual and augmented reality display and interaction technologies. In addition, this discussion of devices considered not only display contents but also the possibilities for direct interaction. The chapter also presents a set of examples that use different devices in data-driven storytelling, reflecting on how to tell DDSs when using different devices and media.

Chapter 7: From Analysis to Communication: Supporting the Lifecycle of a Story

This chapter describes the lifecycle of visual data stories, including the tools and methods that authors employ to create visual stories, the processes they go through, and the major pain points they experience. The discussion of current practices, as presented, is based on interviews with nine professional data storytellers. Each of these interviews explored the participant's experience with one past story production project. The chapter focuses on the visual data storytelling process, from conception through production, including data collection and preparation, data analysis, story development, and visual presentation. Also included is a detailed description of the main roles and activities that storytellers engage in as they turn raw data into a visually shared story and the tools they use to support their work. Based on the example projects described by the participants, the process of story production is summarized, an overview of the tools that are in use is given, and opportunities for research and design are detailed.

Chapter 8: Organizing the Work of Data-Driven Visual Storytelling

One of the challenges of telling compelling, effective DDSs is how a group organizes their teams, skillsets, and workflow. In this chapter, we explore different approaches to working with data and visualizing data in three sectors: design studios, media, and nonprofits and nongovernmental organizations. This chapter explores what teams, tools, and organizational structures these groups use to work with data and tell narrative stories. Their experiences and lessons learned can provide valuable insight for other organizations as they seek to develop their own workflow to effectively visualize and communicate their data, analysis, and stories.

Chapter 9: Communicating Data to an Audience

Communicating data in an effective and efficient story requires the content author to recognize the needs, goals, and knowledge of the intended audience. Do we, the authors, need to explain how a chart works? It depends on the audience. Does the data need to be traced back to its source? Depends on the audience. Can we skip obvious patterns and correlations and dive right into the deeper points? Depends on the audience. And so on. Thus, to effectively communicate ideas and concepts, content authors need to think carefully about how their work best fits the needs of the audience. This chapter explores design considerations relating to audience knowledge and goal contexts, and considers the difference between the theory of what we might know and the reality of what we can know.

Chapter 10: Ethics in Data-Driven Visual Storytelling

Many questions that relate to ethics arise in data-driven storytelling. Is the sample representative, have we thought of the bias of whoever collected or aggregated the data, can we extract a certain conclusion from the dataset, is it implying something the data does not cover, does the visual device, or the interaction, or the animation affect the interpretation that the audience can have of the story? These are questions that anyone that has produced or edited a data-driven visual story has, or at least should have, been confronted with. After introducing the reasons and implications of ethics in this book, this chapter looks at the risks, caveats, and considerations at every step of the process, from the collection/acquisition of the data to the analysis, presentation, and publication, with many points illustrated through an example of an ethical consideration.

Chapter 11: Evaluating Data-Driven Stories and Storytelling Tools

This chapter provides a review of how DDSs and the tools used to produce them are evaluated. Evaluation is a far-reaching concept; among the topics discussed in this chapter include the evaluation of a DDS in a newsroom context as well as the evaluation of novel storytelling tools and techniques in academic research settings. The discussion spans a diverse set of goals, acknowledging the different perspectives of storytellers, publishers, readers, tool builders, and researchers. It also reviews possible criteria for assessing whether these goals are met, as well as evaluation methods and metrics that address these criteria. This chapter is intended to serve as a guide for those considering whether and how they should evaluate the stories they produce or the storytelling tools or techniques that they develop.

FUTURE DIRECTIONS

Many questions arise as interactive visualizations are used in situations beyond data exploration by data experts, such as the focus in this book on communication to a broader audience. Research on the understanding of static images in cognitive psychology and perception may need to be extended to encompass more advanced techniques (videos and interactive applications). Visualization literacy, or the ability to extract, interpret, and make meaning from information presented in the form of an interactive data visualization, is also a crucial component in data-driven storytelling. Assessing the visualization literacy of an audience and developing techniques to better teach how to decode interactive visualizations has started to attract the attention of our research community.* Still, there remains considerable exciting research that can to be done to contribute to a well-informed society. For example, research on how visualizations can lie (Tufte 1984) or at least how they may introduce bias in the reader's mind has focused on static visual representations. Now, opportunities, that are perhaps essential, are developing for research on the process of understanding the effects of interactivity on how interpretation emerges. Similarly, it is crucial for advancing research in visualization to assess the role data-driven storytelling can play in easing the comprehension of messages or in increasing their memorability.

Another future direction for research regards the evolution of our society in light of trends in data. Our society has entered a data-driven era in which not only are enormous amounts of data being generated every day, but also growing expectations are placed on their analysis (Thomas and Cook 2005). Analyzing these massive and complex datasets is essential to making new discoveries, communicating them, and creating benefits for people. In regards to this data deluge, what remains constant is our own cognitive ability to make sense of the data and make reliable, informed decisions. In the future, data-driven storytelling techniques will still be applicable even with growing data size and integrate advanced machine learning and data mining algorithms. New devices and interactive visualization systems will provide tools to support big-data storytelling.

* EuroVis 2014 Workshop: Towards Visualization Literacy. https://www.kth.se/profile/marior/page/eurovis-2014-workshop-towards-visualiza/.

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